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(54) **PROCESS FOR THE PREPARATION OF
OSPEMIFENE**

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67/297 (2013.01); **C07C 69/24** (2013.01);
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(58) **Field of Classification Search**

CPC **C07C 41/26**
See application file for complete search history.

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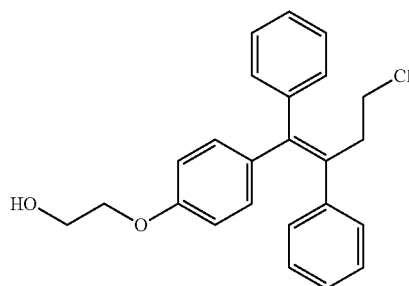
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ABSTRACT

The present invention is related to the process for the prepa-
ration ospemifene or (Z)-2-[4-(4-chloro-1,2-diphenyl-but-1-
enyl)phenoxy]ethanol (I) and to intermediate compounds
used in the process.



(I)

30 Claims, No Drawings

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PROCESS FOR THE PREPARATION OF OSPEMIFENE

CROSS REFERENCE TO RELATED APPLICATION

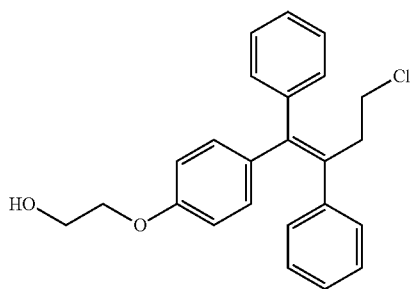
This application is a National Stage entry under 35 USC 371 of PCT/FI2013/000039, filed on Oct. 17, 2013, which is a nonprovisional application of U.S. Provisional Patent Application No. 61/716,171, filed on Oct. 19, 2012.

FIELD OF THE INVENTION

The invention is related to a process for the preparation of ospemifene and to intermediate compounds used in the process.

BACKGROUND OF THE INVENTION

Ospemifene or (Z)-2-[4-(4-chloro-1,2-diphenyl-but-1-enyl)phenoxy]ethanol is represented by formula (I):



Ospemifene is an estrogen receptor agonist/antagonist currently investigated e.g. for the treatment of vulvar and vaginal atrophy due to menopause.

Preparation of ospemifene starting from Z-4-(4-hydroxy-1,2-diphenyl-but-1-enyl)phenol has been described in WO 96/07402. Use of McMurry coupling reaction for the manufacture of ospemifene has been described in WO 2008/099059 and WO 2011/089385. These methods suffer from the drawback that large amounts of expensive reagents or solvents, such as titanium tetrachloride, LiAlH_4 , and 2-Me-THF, are needed:

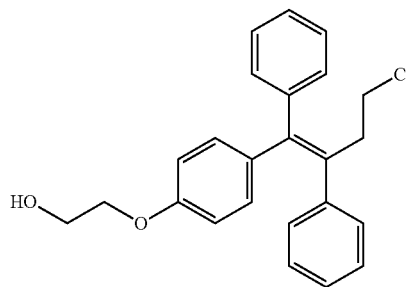
Thus, it is desirable to provide an improved method for producing ospemifene in high yield and purity the method also being economically feasible and suitable for use in a large scale.

SUMMARY OF THE INVENTION

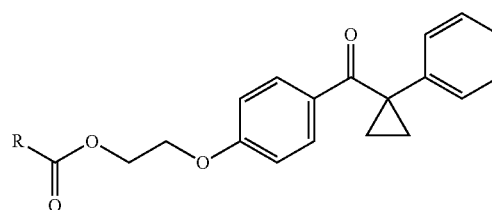
The present invention provides a process for the preparation of a compound of formula (I)

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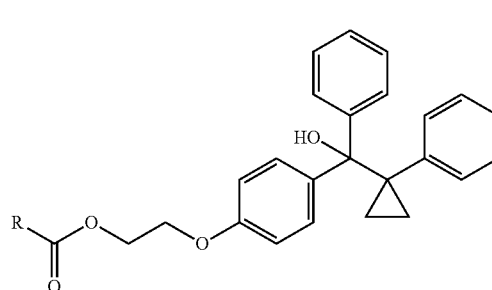
(I)



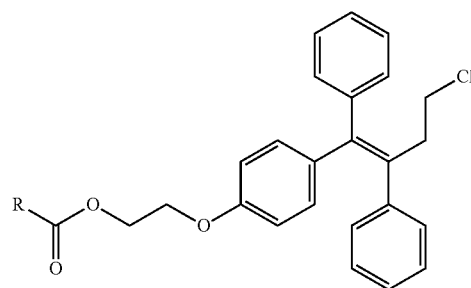
which process comprises
(a) reacting a compound of formula (III)



wherein R is a protecting group tolerant to Grignard or other organometallic reagents, with phenylmagnesium halide to produce a compound of formula (IV)



wherein R is as defined above, and
(b) treating the compound of formula (IV) with hydrochloric acid to produce a compound of formula (V)



wherein R is as defined above, and
(c) cleaving the ester bond of a compound of formula (V) wherein R is as defined above, to give a compound of formula (I).

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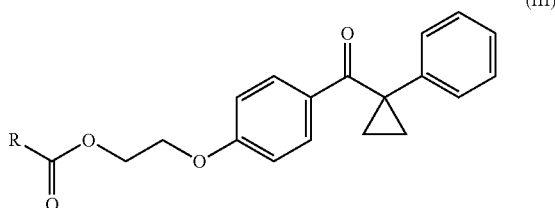
In another aspect, the present invention provides a process for the preparation of a compound of formula (I) comprising, the step of treating the compound of formula (IV), wherein R is a protecting group tolerant to Grignard or other organometallic reagents, with hydrochloric acid to produce a compound of formula (V), and cleaving the ester bond of a compound of formula (V) to give a compound of formula (I).

The invention is also directed to novel compounds of formula (III) and (IV) wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.

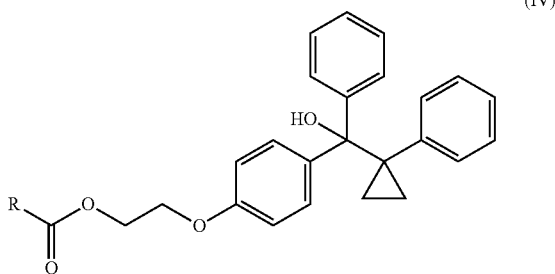
DETAILED DESCRIPTION OF THE INVENTION

The term "lower alcohol" means C₁₋₅ alcohol, preferably C₁₋₄ alcohol. Representative examples include methanol, ethanol, isopropanol and butanol, particularly preferred is methanol and ethanol.

In accordance with the present invention the compound of formula (III)



wherein R is a protecting group tolerant to Grignard or other organometallic reagents, is reacted with phenylmagnesium halide to produce a compound of formula (IV)

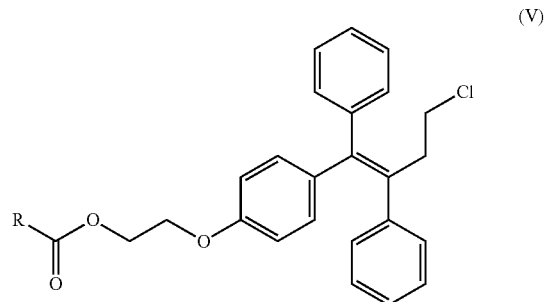


wherein R is as defined above.

The above reaction is based on the nucleophilic addition of a phenylmagnesium halide (Grignard reagent), such as phenylmagnesium chloride or phenylmagnesium bromide, to the carbonyl group of the compound of formula (III). The reaction is carried out in suitable solvent, such as diethyl ether or THF, under nitrogen atmosphere. The reagents are suitably added at room temperature and the mixture is heated, for example to about 60° C. The reaction is typically completed within about 2-3 hours. The reaction can be quenched e.g. with addition of saturated NH₄Cl-solution. Phenylmagnesium halide reagent is at typically used in molar excess, e.g. in 1.5-2 molar equivalents per compound of formula (III). The resulting compound of formula (IV) can be isolated, if desired, by evaporation of the solvents and subsequent crystallization or the crude compound can be forwarded directly to the next step.

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In the next step the compound of formula (IV) is subjected to dehydration and ring-opening reaction by treating it with hydrochloric acid to produce the ester compound of formula (V).

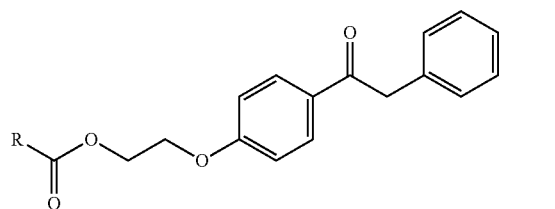


Thus, the compound of formula (IV) is dissolved in a suitable solvent such as dichloromethane (DCM) or toluene and this solution is added slowly to aqueous HCl solution, such as 30% HCl solution. The reaction is suitably carried out at room temperature. The reaction is typically completed within less than one hour.

The resulting ester of formula (V) is particularly suitable for being isolated and purified by crystallization before its use in the next reaction step. Thus, after completion of the ring opening reaction the reaction mixture can be poured on saturated NaHCO₃ solution and the organic phase is recovered. The organic phase is preferably evaporated and the crystallization solvent is added. Suitable crystallization solvents include plain lower alcohols, such as methanol and ethanol. Particularly suitable crystallization, solvents are methanol or ethanol essentially in the absence of water, thereby giving the ester of formula (V) in high yield and purity. The mixture of crystallization solvent and crude ester of formula (V) is stirred and suitably heated to achieve dissolution. The mixture may then be cooled to about 40° C. and seeded with the desired Z-isomer. Cooling is continued over a period of time (preferably slowly, e.g. over more than one hour) to room temperature or below, e.g. below 15° C., in order to achieve crystallization. The mixture is suitably stirred in this temperature for more than 3 hours, e.g. for 12 hours. The crystalline ester of formula (V) is filtered, washed and dried preferably under reduced pressure. The chemical purity of the crystallized compound of formula (V) is at this stage typically higher than 92% and the amount of E-isomer less than 5%. The end product may be further recrystallized if desired.

Compounds of formula (III) can be prepared using the methods known in the art.

For example, compound of formula (III) can be suitably prepared by reacting a compound of formula (II)



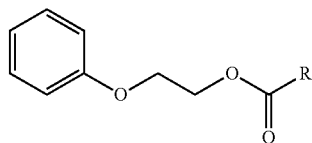
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with a compound of formula $X_1-CH_2-CH_2-X_2$, wherein X_1 and X_2 is a leaving group and R is a protecting group tolerant to Grignard or other organometallic reagents. Suitable leaving groups X_1 and X_2 include, but are not limited to, halogens, para-toluenesulfonate ($CH_3C_6H_4SO_2O-$), methanesulfonate (CH_3SO_2O-) and trifluoromethanesulfonate (CF_3SO_2O-) groups. According to one embodiment of the invention X_1 and X_2 are halogens, in particular X_1 is Br and X_2 is Cl. The reaction between the compound of formula (II) and the compound of formula $X_1-CH_2-CH_2-X_2$ is suitably carried out in the presence of a phase transfer catalyst (PTC), such as quaternary ammonium or phosphonium salts. Examples of phase transfer catalyst include tetrabutylammonium hydrogensulfate (TBAHS), benzyltrimethylammonium chloride and hexadecyltributylphosphonium bromide. Thus, compound of formula (II) is dissolved in suitable solvent such as toluene under nitrogen atmosphere at room temperature followed by the addition of phase transfer catalyst such as TBAHS and aqueous NaOH solution (e.g. 50% NaOH solution) to the reaction mixture. The resulting two-phase system is stirred vigorously and the compound of formula $X_1-CH_2-CH_2-X_2$ is added dropwise. The reaction is typically completed within 12 hours. The organic phase is isolated, washed, filtered, dried and evaporated to obtain the compound of formula (III).

Alternatively, the reaction between the compound of formula (II) and the compound of formula $X_1-CH_2-CH_2-X_2$ can be carried out in an organic solvent, such as DMSO, DMF or THF, in the presence of a base such as NaH, K-, Na- or LiOBu-t, or corresponding carbonates.

Compounds of formula (II) can be prepared using the methods known in the art.

For example, compound of formula (II) can be suitably prepared by reacting a compound of formula (VI)

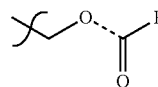


wherein R is C_{1-5} alkyl or an optionally substituted phenyl, with 2-phenylacetic acid. Typically, the reaction is catalyzed by a Brønsted acid, such as polyphosphoric acid (PPA). Thus, to warmed PPA is added compound of formula (VI) and 2-phenylacetic acid. After stirring for about 3 h, water is added and the mixture, is stirred further, at room temperature for about 2 h. The precipitated compound of formula (II) is filtered, washed and dried, and, if desired, recrystallised from suitable solvent, such as hexane/isopropanol (1:1).

According to one embodiment of the invention, particularly suitable compounds of formula (II), (III), (IV), (V) and (VI) are those wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl. Particularly preferred compounds of formula (II), (III), (IV), (V) and (VI) are those wherein R is t-butyl.

The compound of formula (I) (ospemifene) is obtained by subjecting the compound of formula (V) to cleavage of the ester bond (dashed bond below) of the compound of formula (V)

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such that the hydroxyl group of ospemifene is formed.

The cleavage of the ester bond of the compound of formula (V) can be carried out by using well known methods such hydrolysis or a reductive cleavage.

Hydrolysis of the ester bond of the compound of formula (V) can be catalysed by a base or acid. A base catalysed hydrolysis is particularly preferred. The base catalysed hydrolysis can be carried in a suitable solvent such as aqueous THF or aqueous THF/MeOH mixture in the presence of a suitable base, such as NaOH or LiOH at room temperature for a time sufficient to complete the hydrolysis. When the hydrolysis is carried out at room temperature, the reaction is completed typically within 12 hours or less. Thereafter, water and suitable organic solvent such as EtOAc is added and the organic phase is washed, dried, filtered and concentrated. Ospemifene can be conveniently isolated from the residue by crystallization from a suitable crystallization solvent. Preferred solvents for crystallization are C_{1-5} alcohols, particularly methanol, ethanol or isopropanol, or aqueous. C_{1-5} alcohols such as aqueous methanol (e.g. 80% or 90% methanol).

Reductive cleavage of the ester bond of the compound of formula (V) to obtain ospemifene can be carried out in the presence of a reducing agent such as lithium aluminium hydride in a suitable organic solvent such as toluene, THF, hexane or xylene or mixture thereof. The reaction is suitably carried out at room temperature and under nitrogen atmosphere. The reaction may be suitably quenched by addition of saturated NH_4Cl -solution. Organic phase is washed, dried, filtered and concentrated. Ospemifene can be conveniently isolated from the residue by crystallization from a suitable crystallization solvent as described above:

The invention is further illustrated by the following non-limiting examples.

EXAMPLES

Example 1

Preparation of 2-phenoxyethyl pivalate

2-Phenoxyethanol (50 g, 0.362 mol) was dissolved in dichloromethane (500 ml) and the solution was cooled to 0-5° C. Triethylamine (101 ml, 0.724 mol) was added to the cooled solution followed by pivaloyl chloride (53.5 ml, 0.434 mol) maintaining the temperature, below 5° C. After additions the mixture was stirred at 5° C. for 30 min and at room temperature for 12 h. The reaction was quenched by addition of 1M HCl-solution (300 ml) and stirred vigorously. The phases were separated and organic phase was washed with saturated $NaHCO_3$ -solution (2×150 ml), water (1×100 ml) and brine (1×100 ml). After drying (Na_2SO_4) and filtration the solvent was evaporated yielding the title compound (76.78 g, 0.345 mol, 95%) as a yellow oil. 1H -NMR (400 MHz, $DMSO-d_6$) δ (ppm): 7.31-7.27 (2H, m, ArH), 6.96-6.93 (3H, m, ArH), 4.34 (2H, m, CH_2CH_2OPiv), 4.19 (2H, m, $ArOCH_2CH_2$), 1.13 (9H, s, 3×Me). ^{13}C -NMR (100 MHz, $DMSO-d_6$) δ (ppm): 177.7, 158.7, 130.1, 121.1, 114.9, 66.1, 62.9, 38.5, 27.6.

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Example 2

Preparation of 2-(4-(2-Phenylacetyl)phenoxy)ethyl pivalate

Polyphosphoric acid (PPA) (250 g) was charged to a reaction vessel and warmed to 50° C. (bath temperature) with mechanical stirring. 2-Phenylacetic acid (30.6 g, 0.225 mol) was added to PPA followed by 2-phenoxyethyl pivalate (50 g, 0.225 mol). After 3 hours TLC and HPLC indicated full conversion and water (1000 ml) was added. The mixture was stirred at room temperature for 2 h. The precipitated product was filtered and washed with water (300 ml). After drying in vacuo the crude product (65 g) was re-crystallized with hexane/i-PrOH 1:1 yielding the title compound as slightly yellow solid (51.49 g, 0.151 mol, 67%). ¹H-NMR (400 MHz, DMSO-d₆) δ (ppm): 8.02 (2H, d, J=9.2 Hz, ArH), 7.32-7.22 (5H, m, ArH), 7.07 (2H, d, J=8.8 Hz, ArH), 4.37 (2H, m, CH₂CH₂OPiv), 4.31 (2H, s, ArCH₂CO), 4.3 (2H, m, ArOCH₂CH₂), 1.12 (9H, s, 3×Me). ¹³C-NMR (100 MHz, DMSO-d₆) δ (ppm): 196.4, 177.7, 162.6, 135.8, 131.2, 129.9, 129.8, 128.7, 126.8, 114.8, 66.5, 62.7, 44.8, 38.6, 27.2.

Example 3

Preparation of

2-(4-(1-Phenylcyclopropanecarbonyl)phenoxy)ethyl pivalate

2-(4-(2-Phenylacetyl)phenoxy)ethyl pivalate (15 g, 44.1 mmol) was dissolved in nitrogen bubbled toluene (150 ml) and stirred under nitrogen atmosphere for 10 min at room temperature. Tetrabutylammonium hydrogensulfate (1.496 g, 4.41 mmol) catalyst was added to the stirred solution followed by 50% NaOH-solution (60 ml, 1137 mmol). The two-phase system was stirred vigorously for 10 min. 1-Bromo-2-chloroethane (9.17 mL, 110 mmol) was dissolved in toluene (35 ml) and added dropwise to the stirred reaction mixture. After 12 hours the starting material was consumed and water (100 ml) was added. The phases were separated and the aqueous layer was extracted with toluene (50 ml). The combined toluene phases were washed with water (100 ml) and brine (100 ml). After drying (Na₂SO₄) and filtration toluene was removed in vacuo. Crude title compound (15.39 g, 42 mmol, 95%) was obtained as sticky brown oil contaminated with 15% of O-alkylated by-product. ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 7.80 (2H, d, J=9.2 Hz, ArH), 7.26-7.16 (5H, m, ArH), 6.77 (2H, d, J=8.8 Hz, ArH), 4.37 (2H, t, J=4.8 Hz, CH₂CH₂OPiv), 4.15 (2H, t, J=5.0 Hz, ArOCH₂CH₂), 1.60 (2H, AB-system, J=4.4 Hz, CH₂CH₂), 1.32 (2H, AB-system, J=4.4 Hz, CH₂CH₂), 1.17 (9H, s, 3×Me). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 198.6, 178.9, 162.1, 141.7, 132.3, 130.2, 129.1, 127.9, 126.8, 114.2, 67.0, 62.8, 39.2, 35.0, 27.5, 16.1.

Example 4

Preparation of (Z)-2-(4-(4-Chloro-1,2-diphenylbut-1-en-1-yl)-phenoxy)ethyl pivalate

Crude 2-(4-(1-Phenylcyclopropanecarbonyl)phenoxy)ethyl pivalate (15.3 g, 41.8 mmol) was dissolved in tetrahydrofuran (THF) (200 ml) under nitrogen with stirring. 1 M THF-solution of phenylmagnesium chloride (35.5 ml, 71 mmol) was added dropwise to the solution at room temperature. After addition the reaction was warmed to 60° C. and kept at this temperature for two hours. The reaction was

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quenched by addition of saturated NH₄Cl-solution (300 ml). The pH was adjusted to 4 with 5% HCl-solution and THF-phase was separated. The aqueous phase was extracted with dichloromethane (2×75 ml), combined with THF-phase, and washed with water (100 ml) and brine (100 ml). After drying (Na₂SO₄) and filtration the solvents were evaporated and crude cyclopropylcarbinol intermediate (21 g) was directly submitted to the ring-opening step. The crude cyclopropylcarbinol intermediate was dissolved in dichloromethane (DCM) (150 ml) and treated with 30% HCl-solution (120 ml). After 60 min the dehydration and ring-opening was complete and reaction mixture was poured on saturated NaHCO₃-solution (350 ml). The phases were separated and DCM-phase was washed with water (100 ml) and brine (100 ml). After drying (Na₂SO₄) and filtration the solvent was evaporated. The residue was dissolved in boiling methanol, cooled to 40° C. and seeded. After stirring at room temperature (12 h) the precipitated title compound was filtered and washed with cold MeOH. The title compound was obtained as a white solid (5.4 g, 11.7 mmol, 28% over two steps). ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 7.39-7.13 (6H, m, ArH), 6.79 (2H, d, J=8.8 Hz, ArH), 6.56 (2H, d, J=8.8 Hz, ArH), 4.31 (2H, t, J=4.4 Hz, CH₂CH₂OPiv), 4.04 (2H, t, J=4.8 Hz, ArOCH₂CH₂), 3.41 (2H, t, J=7.6 Hz, ClCH₂CH₂), 2.92 (2H, t, J=7.6 Hz, ClCH₂CH₂), 1.17 (9H, s, 3×Me). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 178.5, 156.8, 142.8, 141.6, 140.9, 135.3, 135.2, 131.7, 129.5, 129.4, 128.4, 128.2, 127.0, 126.6, 113.6, 65.7, 62.7, 42.8, 38.7, 38.6, 27.1.

Example 5

Preparation of (Z)-2-[4-(4-chloro-1,2-diphenylbut-1-en-1-yl)-phenoxy]ethanol (ospemifene) by Base Hydrolysis of Pivaloyl-Group

(Z)-2-(4-(4-Chloro-1,2-diphenylbut-1-en-1-yl)phenoxy)ethyl pivalate (1 g, 2.16 mmol) was dissolved in THF (8 ml) followed by addition of MeOH (1 ml) and water (1 ml). Sodium hydroxide (0.1 g, 2.5 mmol) was added in one portion and the reaction was stirred at room temperature for 12 h. After completion of the reaction the mixture was partitioned between water (20 ml) and EtOAc (20 ml). Organic phase was washed with water (20 ml) and brine (20 ml), dried (Na₂SO₄), filtered and concentrated. The residue was crystallized from i-PrOH yielding ospemifene (0.29 g, 35%) as a white solid. ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 7.37 (2H, t, J=8 Hz, ArH), 7.29 (3H, t, J=7.2 Hz, ArH), 7.20 (2H, t, J=7.6 Hz, ArH), 7.16-7.13 (3H, m, ArH), 6.80 (2H, d, J=8.8 Hz, ArH), 6.57 (2H, d, J=8.8 Hz, ArH), 3.94 (2H, t, J=4.4 Hz, ArOCH₂CH₂OH), 3.87 (2H, m, ArOCH₂CH₂OH), 3.42 (2H, t, J=7.2 Hz, ClCH₂CH₂), 2.92 (2H, t, J=7.2 Hz, ClCH₂CH₂), 1.95 (1H, t, J=6.4 Hz, OH). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 157.2, 143.2, 142.1, 141.3, 2×135.7, 132.2, 130.0, 129.8, 128.8, 128.7, 127.4, 127.0, 113.9, 69.3, 61.8, 43.3, 39.0.

Example 6

Preparation of (Z)-2-[4-(4-chloro-1,2-diphenylbut-1-en-1-yl)-phenoxy]ethanol (Ospemifene) by Reductive Cleavage of Pivaloyl-Group

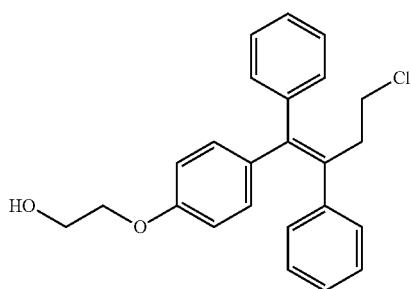
(Z)-2-(4-(4-Chloro-1,2-diphenylbut-1-en-1-yl)phenoxy)ethyl pivalate (3.5 g, 7.56 mmol) was dissolved in toluene (35 ml) and stirred under nitrogen for 5 min at room temperature.

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Lithium aluminium hydride solution (1 M in THF) (7.56 ml, 7.56 mmol) was added dropwise to the reaction and the mixture was stirred at room temperature for 30 min. After HPLC indicated completion, the reaction was quenched by addition of saturated NH_4Cl -solution (75 ml). Additional amount of toluene (30 ml) was added and the phases were separated. The organic phase was washed with water (50 ml), brine (50 ml), dried (Na_2SO_4), filtered and concentrated in vacuo. The residue was crystallized from 90% MeOH yielding ospemifene (1.75 g, 61%) as a white solid.

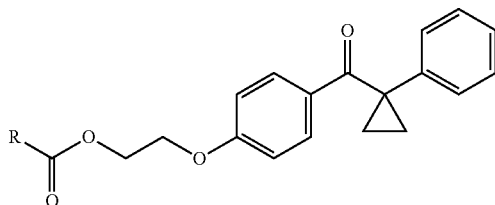
The invention claimed is:

1. A process of preparing a compound of formula (I)



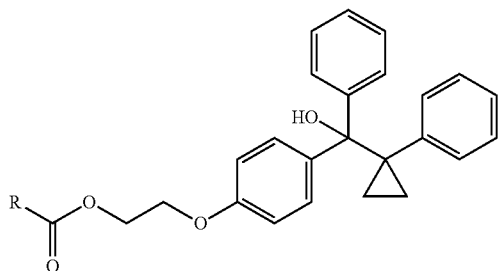
which process comprises

(a) reacting a compound of formula (III)



wherein R is a protecting group tolerant to Grignard or other organometallic reagents,

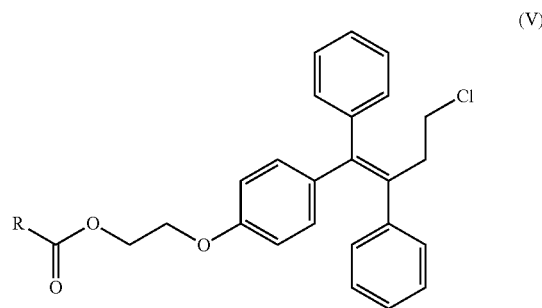
with phenylmagnesium halide, thereby obtaining a compound of formula (IV)



wherein R is as defined in formula (III),

(b) treating the compound of formula (IV) with hydrochloric acid, thereby obtaining a compound of formula (V)

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wherein R is as defined as in formula (III), and (c) cleaving the ester bond of the compound of formula (V), thereby obtaining the compound of formula (I).

2. The process according to claim 1, wherein the phenylmagnesium halide is phenylmagnesium chloride.

3. The process according to claim 1, further comprising isolating the compound of formula (V) by crystallization.

4. The process according to claim 3, wherein the crystallization of the compound of formula (V) is from a lower alcohol.

5. The process according to claim 4, wherein the lower alcohol is methanol or ethanol.

6. The process according to claim 1, wherein (c) cleaving the ester bond of the compound of formula (V) is carried out by a base catalyzed hydrolysis or a reductive cleavage.

7. The process according to claim 6, wherein (c) cleaving the ester bond comprises reductive cleavage in the presence of lithium aluminium hydride.

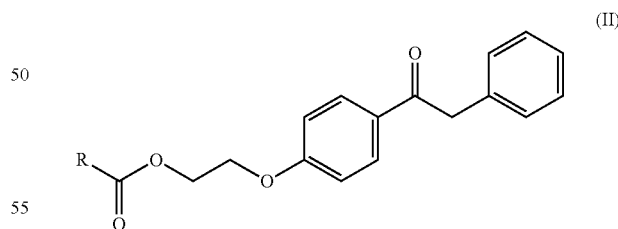
8. The process according to claim 1, further comprising isolating the compound of formula (I) by crystallization.

9. The process according to claim 8, wherein isolating the compound of formula (I) comprises crystallizing the compound of formula (I) from C_{1-5} alcohol or from a mixture of C_{1-5} alcohol and water.

10. The process according to claim 1, wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.

11. The process according to claim 10, wherein R is t-butyl.

12. The process according to claim 1, further comprising preparing the compound of formula (III) by reacting a compound of formula (II)



with a compound of formula $\text{X}_1\text{—CH}_2\text{—CH}_2\text{—X}_2$, wherein X_1 and X_2 are each a leaving group and R is a protecting group tolerant to Grignard or other organometallic reagents.

13. The process according to claim 12, wherein X_1 is halogen and X_2 is halogen.

14. The process according to claim 13, wherein X_1 is Br and X_2 is Cl.

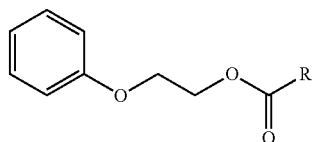
15. The process according to claim 12, wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.

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16. The process according to claim 15, wherein R is t-butyl.
 17. The process according to claim 12, wherein reacting the compound of formula (II) with the compound of formula $X_1-CH_2-CH_2-X_2$ is carried out in the presence of a phase transfer catalyst.

18. The process according to claim 17, wherein the phase transfer catalyst is tetrabutylammonium hydrogensulfate (TBAHS).

19. The process according to claim 12, further comprising preparing the compound of formula (II) by reacting a compound of formula (VI)

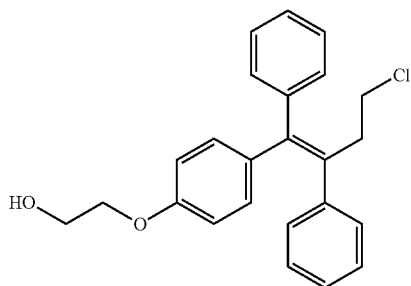


wherein R is a protecting group tolerant to Grignard or other organometallic reagents, with 2-phenylacetic acid.

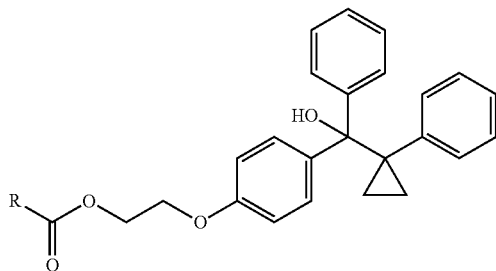
20. The process according to claim 19, wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.

21. The process according to claim 20, wherein R is t-butyl.

22. A process of preparing a compound of formula (I)



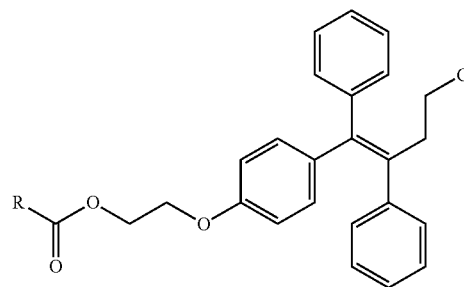
the process comprising treating a compound of formula (IV)



wherein R is a protecting group tolerant to Grignard or other organometallic reagents, with hydrochloric acid, thereby obtaining a compound of formula (V)

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(V)

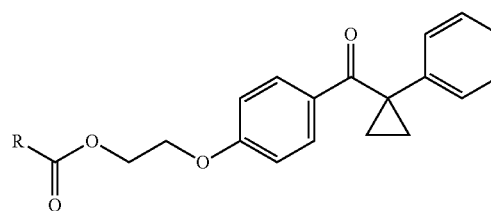


wherein R is as in formula (IV), and cleaving the ester bond of the compound of formula (V), thereby obtaining the compound of formula (I).

23. The process according to claim 2, wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.

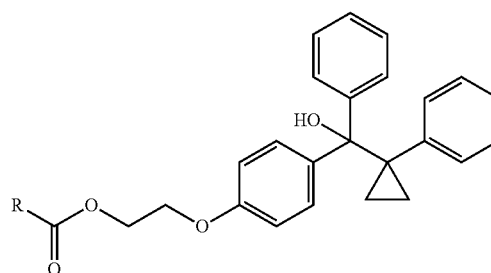
24. The process according to claim 23, wherein R is t-butyl.

25. A compound of formula (III)



wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.
 26. The compound according to claim 25, wherein R is t-butyl.

27. A compound of formula (IV)



wherein R is t-butyl, adamantyl or 2,4,6-trimethylphenyl.
 28. The compound according to claim 27, wherein R is t-butyl.

29. The process of claim 3, wherein a chemical purity of the compound of formula (V) immediately after the crystallization is higher than 92%.

30. The process of claim 3, wherein the compound of formula (V) immediately after the crystallization has a content of less than 5% of an E-isomer of the compound of formula (V).

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